DOCUMENT RESUME

ED 342 891 CE 060 399

AUTHOR Tedesco, Angelo J.
TITLE Technology Transfer.
PUB DATE Dec 91
NOTE 14p.; Paper presented at the Annual Meeting of the International Vocational Education and Training Association (Los Angeles, CA, December 1991).
PUB TYPE Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Educational Improvement; Educational Needs; Foreign Countries; Postsecondary Education; Secondary Education; Technical Assistance; *Technological Advancement; *Technology Transfer; *Transfer of Training; *Vocational Education

ABSTRACT

In the future, it will become more important and more challenging than ever for the vocational education system to deliver a competent work force. To develop a system that can produce competent workers, teachers and administrators must understand how cognitive domains relate to technology transfer--that is, to what extent can students perform the activities for which they were trained? The domains of knowledge, skill, and attitude must be in balance if there is to be a maximum transfer of technology by vocational programs. Basic levels of learning can be characterized as "general knowledge," "working knowledge," and "qualified knowledge." Qualified knowledge represents the highest level. A student who has reached it has the ability to recognize common factors and bring new sources and types of information to bear on a new solution. At this level, knowledge and skills are learned in sufficient breadth and depth for the student to transfer earlier learnings to a new set of circumstances, including reflecting on the consequences expected if action is taken. The challenges of technology transfer vary by the settings in which they occur; they can involve developed and developing nations. The process includes technology selection, technology transfer, use of the technology, adaptation of the technology to local needs, improvement, and the generation of new technologies. Throughout this process, training is required if the technology transfer is to be successful. (KC)

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TECHNOLOGY TRANSFER

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Presented by:

ANGELO J. TEDESCO

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The Domains of Learning as They Relate to

TECHNOLOGY TRANSFER

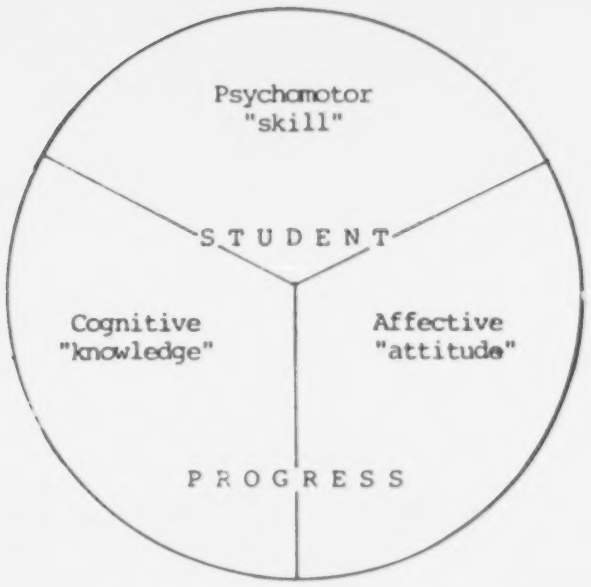
As we move through the twenty-first century the need for Vocational Education to develop an educational system capable of delivering a competent work force will become more and more challenging. To develop this system, teachers and administrators must understand how the domains in which we learn relate to technology transfer. That is, to what extent can the student perform the activity for which he was trained? It is also important that they realize how more emphasis on one domain or the other may be necessary. How the students educational background has prepared him in the cognitive, psychomotor and affective domains will determine how effectively the system performs.

The cognitive domain deals with knowledge and intellectual learning. A student performance objective requiring a student to calculate the cost of a product would fall into the cognitive domain, the same as one that requires a student to describe a process, a process such as writing a description of the procedure for shutting down an oxyacetylene torch. Behavior in the cognitive domain usually deals with "knowing" something and rarely requires any manipulation beyond writing and speaking.

The psychomotor domain deals with physical skill such as typing, pounding a nail, and manipulating instruments. This domain has four levels, observation, imitation, practice and adaption. At the higher levels in the psychomotor domain the student can apply the skill learned to situations unrelated to the ones in which they were learned. For example, a student who has learned to construct bridges very likely could design the roof structure for a building.

In the affective domain attitudes, values, feelings, and emotions are dealt with. This domain is critical to the learning process and the transfer of technology will not likely reach production capability with out the desire to do so at the lowest educational levels. This desire must continue throughout all stages of the educational process if the student is to receive, value, and respond to the needs of a nation attempting to establish a technically literate work force which has production capability. We may assume some transfer in this domain has taken place when a student (without being prompted) consistently reports to class on time, works and studies diligently while there, and puts the work area in an orderly manner before leaving.

The following figure illustrates how the domains of learning which represent knowledge, skill, and attitude must be in balance if there is to be a maximum transfer of technology by vocational programs.



In a study made by Management Systems International (MSI) to ascertain the progress of technology transfer it was determined that "....it is the transfer of technology mastery which is sought by the Saudies in the next decade." The definition given for technology mastery was "the ability to receive and assimilate, adapt and or produce technology, that is, production capability."

To further clarify the relationship between technology transfer or production capability from one individual or in fact one country to another we should look at the basic levels of learning as they exist in each domain. The first is "general knowledge", concerned primarily with the students' ability to follow directions. To perform most jobs, it is necessary to remember facts. Instruction should be so in depth that students will recognize an item after they have been reminded. The "general knowledge" level requires sufficient knowledge of relationships and associated principles to make the information being learned more meaningful. Students should know sources from which they might obtain information, and they must develop the ability to follow directions This level of learning generally requires no manipulation of instruments other than pencils, and few, if any, hands on exercises are used during instructional activities.

The second level of learning, called "working knowledge," concerns the depth to which a student successfully recalls something which has been learned previously. The student's abilities are developed to the degree that they can interpret diagrams, drawings, tables, and information manuals. At this level, students develop the ability to do such things as translate mathematical word problems into symbolic statements. The development of a working knowledge of an occupation can be achieved by means of conferences, demonstrations, and supervised practice.

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The top level in the three-level classification system is termed "qualified knowledge". This level denotes the progress by which a student, faced with a new problem or situation, has the ability to recognize common factors and bring new sources and types of information to bear on a new solution. At this level, knowledge and skills are learned in sufficient breadth and depth for the student to transfer earlier learnings to a new set of circumstances, including reflecting on the consequences expected if an action is taken. Manipulative skills are developed whereby performance of a task is efficiently and smoothly executed.

These three levels of learning, general knowledge, working knowledge and qualified knowledge are present in each of the three domains of learning and are clearly related to the technology transfer continuum developed by M.S.I. In the M.S.I. report a six step continuum was established. The variables in the continuum were: replication, operation, consultation, collaboration modification and innovation. In this continuum one can clearly observe the simple to complex sequence which is required for technology transfer to take place. It may now be illustrated in figure two, how the domains of learning are divided into levels of difficulty and how these levels can be sequenced to insure a continuum for technology transfer.

DOMAINS OF LEARNING

		COGNITIVE	AFFECTIVE	PSYCHOMOTOR
REPLICATION				
LEVELS of LEARNING	GENERAL	knowledge comprehension	receive model	observation initiation
	WORKING	application analysis	responding valuing	practice
	QUALIFIED	synthesis evaluation	organizing characterizing	adaption INNOVATION

TECHNOLOGY TRANSFER

The challenges of technology transfer are as varied as the settings in which those transfers occur. Technology is exchanged among the Western industrial nations and the newly industrializing countries. It is exported from these nations to the emerging democracies of Eastern Europe with their aging plants and infrastructures. Technological information and hardware flow from the industrial North to the developing nations of the Southern hemisphere. Each of these transactions presents a unique set of problems to the managers and technicians charged with making technology transfer work. Today, some of the greatest challenges are found in the developing countries of the Third World, where the technological gap is widest.

Technology transfer involves the movement of knowledge (technical, scientific, managerial) and usually the products of technology, the hardware, from the country of their creation to that of the buyer-user. Technology transfer implies a product of some sort, whether it is fertilizer for export, medical services for the local population, training manuals for office workers, or proficiency in the operation of a dynometer or computer network. What is transferred is not simply a turnkey fertilizer plant or a fleet of ambulances, but the capability to produce (MSI, 1986). Technology transfer involves the sender and the receiver at the macro and micro levels - from the consideration of government incentives, to the acknowledgement of organizational constraints, to an awareness of the skills of the local worker. Labor unions, legislatures, landlords and consumers are all actors with roles of varying importance.

This process can be examined in a framework of sequential stages of development: technology selection, transfer, utilization, adaption, improvement, and the generation of new technologies (Kaplinsky, 1990).

Selecting Technology

Those making decisions of selection can precipitate failure by spending the time and money at the front end in the collection and consideration of information. Competent, informed technology selection requires the collection and analysis of tremendous amounts of data. Too often, planners judge this information-gathering process prohibitively expensive and confusing. Many fall back on imperfect, but near and familiar mechanisms of selection: the advice of friends, personal prejudices, technologies from countries where they have studied, fancy advertising campaigns, familiar brand or company names (Kaplinsky, 1990). An inaccurate assessment of available raw materials, a failure to understand social constraints on the provision of family planning services, can have disastrous consequences for the technology provider.

A common problem in the selection process is the effect of unequal goals or motivations between the supplier and recipient. In the case of government clients, there is a temptation to choose projects that will lend the greatest prestige. This temptation will be especially seductive in the case of development aid where there is little cost to the national economy (Aasen, et al, 1991).

Those charged with the selection of appropriate technologies should consider all of the variables that will influence the fortune of the chosen technology: government support in the form of services and physical infrastructure, local and international economic conditions, social-cultural adaptability, and physical and human resources.

Infrastructure support typically provided by governments includes transportation, telecommunications, utilities, training subsidies, education, and health care. The "optimal function of a given technology requires infrastructure equipment of a certain quantity and quality" (Lorentzen, 1990). Planners are forced to make choices based on the level of infrastructure support:

> They can adapt the project fully to the given conditions by limiting its scope, reducing its quality and finding new ways to use the given resources. This kind of solution preserves the existing technological level of development. No important technological changes can take place without corresponding infrastructure development. This strategy is called "appropriate technology" and stagnation is an inherent characteristic of it.
>
> Alternatively the carriers of technology can decide to dedicate some of their own resources to compensate for the deficiencies of the given infrastructure, typically through in-house training and education, private road construction and other private systems of transportation. This solution implies a spread of resources away from the main activity.... and leads to an increasing internal integration and complexity of organization. It thus diminishes the possibilities of specialization... This strategy implies a move of technology from developed to less developed countries.
>
> A general change of the infrastructure corresponding to the technological change can be considered. However this possibility is seldom within the reach of individual actors at the micro-level. ... This is the only (strategy) with far reaching and dynamic implications. A simultaneous change of technology and infrastructure is optimal to a technological and socioeconomic change and should always be considered a crucial point in any policy of technological change (Lorentzen, 1990).

Favorable economic conditions include a healthy export economy providing sources of private and public capital for investment, a program of government subsidies for training and other relevant factors.

Social-cultural adaptability. Not all societies are well-disposed to the assimilation of new technologies of external origins. While a pre-industrial Europe yielded nothing of its religious and philosophical beliefs to foreign influences, it readily adopted whatever it found useful and expedient in matters technical and scientific. Europe happily embraced three of the great technologies of the past from China - gunpowder, printing and the compass; however, Chinese xenophobia and the low esteem that the ruling bureaucracy held for merchants and industrialists precluded Chinese acceptance of later innovations from a progressive Europe. Acceptance or even an expressed interest in European technology would constitute an admissions of not only technical, but cultural and racial inferiority (Stewart, 1990; Hall, 1957). Conversely, the Japanese have long believed that they can freely adopt competing technologies without any effect to their traditions and culture.

Physical and human resources. A population that is well-educated and adaptable to rapid change is a prerequisite to successful technology transfer. At the close of the 19th century, the Japanese government expended tremendous efforts in the education of its population (as they continue to do). This effort played no small role in Japan's rise to industrial pre-eminence in this century. However, the education of the populace is not enough; those involved in the transfer process must also have access to the best and the brightest.

Bureaucracies created to facilitate transfer in developing countries often fill counter productive roles. In an attempt to build a national data network, the Singapore government was restrained by an immovable bureaucracy that was ill-suited to the demands of technology transfer. While undertaking to streamline government procedures and reduce the number of administrative layers, government leaders created a quasi-independent agency outside of the civil service, with flexible salary structures and liberal training and promotion policies. This agency was able to attract and keep the minds it needed to insure the projects success (Gilbert, 1990).

Finally, planners must consider environmental constraints and natural resources when selecting technologies. Climate may dictate... A shortage of water on a tropical island may prohibit the processing of...

Transferring Technology

There are five major mechanisms used in the acquisition of technology (Kaplinsky, 1990). The buyer can acquire equity in the technology holder. This "buy-in" can range from complete domination in the form of a wholly-owned subsidiary to a joint venture in which holder and recipient own nearly equal portions. The second mechanism, establishment of a licensing agreement, may give the receiver access to process know-how, product know-how, managerial expertise or technical services. The dominant form of technology transfer is the outright purchase of equipment or know-how. In this approach, continuous expenditures must be made in capital investments and in the maintenance and upgrade of these investments. The fourth approach involves the purchase of know-how in the form of detailed specifications or blueprints, while the fifth calls for the acquisition of technical knowledge through the exchange of human resources.

Utilizing Technology

This is the operational stage of the transfer process. At this point the supplier and recipient attempt the efficient operation of the technology, approximating as much as possible the designed levels of performance. Operational efficiency is dependent on native labor skills and the availability of foreign exchange; on the level and quality of training provided (studies in many countries have demonstrated "learning by doing" is grossly overestimated as a training technique) (Kaplinsky, 1990).

Adapting Technology

Once a technology is "installed" the users may find it necessary to make changes to accommodate local conditions. Physical or climatic factors may force adaptations. For instance, extremes of heat or cold may restrict operating hours of hardware or necessitate equipment modifications. The limited skills of the labor force or absence of a trained maintenance staff may restrict hours of use and necessitate a large, costly inventory of spare parts. Deeply ingrained cultural habits may limit the effectiveness of managerial procedures, or restrict extension of services into certain sensitive areas.

Adaption efforts are often the most difficult of the process and may require external assistance from government or special consultants. It can be one of the most important technological activities the recipient undertakes. Studies in South America and Africa have demonstrated that "the primary source of technological change within firms arose not from formal R & D activities but from an accretion of these relatively minor trouble-shooting efforts to adapt equipment and procedures to local conditions" (Katz, 1987; Kaplinsky, 1978).

Improving Technology

This is a modification stage, requiring complex skills exceeding those used in the adaptation process. Once the process or hardware has been modified to accommodate local conditions, the users may begin to see possibilities for change that will actually stretch the "purchased" capacity of the technology. In Latin America, a shortage of foreign exchange to upgrade or purchase new technologies has been the inspiration for inventive modifications.

Generating Technology

The ability to generate new technologies follows technological mastery. It is in this area that "domestic value added is highest.... and it represents one of the surest paths to a high wage economy, and the high skills which are required to provide manifold opportunities for stimulating employment", (Kaplinsky, 1990). With the exception of the large oil-producing nations, those countries with the highest per capita income are also those with the greatest strength in generating technology. While most developing economies have limited opportunities to reach this peak of technology development, occasionally there are narrow niches of specialization in which developing countries can compete with the best, especially in technologies, which for climatic or other reasons, are especially appropriate for developing countries (Chatterji, 1990).

It is important to maintain a sense of balance between the extreme assertions of unlimited possibilities and insurmountable limitations in evaluating the technology generation abilities of developing countries. It is imperative that government provide policy mechanisms for selecting areas of technological specialization. It is also important to avoid "blue sky" research with its distant payoffs. The Japanese attempted this sort of highly speculative research only after they had learned from "undoing, exploring and then improving other countries' technologies", (Kaplinsky, 1991).

Education and training policies must be tailored to meet the requirements of technology acquisition, adaptation and development. In a model that depicts technology transfer at the individual level (MSI, 1986), six steps are depicted in two phases, beginning with replication. At this step, the technology is installed and operated by the supplier. During this period, the receiver who will eventually assume responsibility for operation is either an observer or is participating in related training elsewhere.

At the operation step, the supplier trains the recipient as operator, although he continues the higher level tasks of design and management.

Efforts to adapt the technology to the recipient's unique needs begin at the consultation step. Based on personal observations and interviews with the recipients, the supplier begins the customizing process while continuing to design, manage and maintain the technology.

During the next phase, the high end of the transfer process begins as the supplier gradually eases into an advisory role, and the recipient assumes complete responsibility for operation and maintenance of the technology. At the collaboration step, the supplier acquires a counterpart or colleague - "an individual who is trained and knowledgeable or who is prepared to be trained in a combination of means, both on and off the job".

The modification step, the recipient begins to assume responsibility for the adaption of the technology to "his specific needs and understandings". The supplier retains design, operation and maintenance responsibility, but increasingly delegates more of this "creative" work to his counterpart.

Innovation is the final step in the technology transfer process. At this point the recipient should have mastered the technology and be able to assume full responsibility for design, management and maintenance.

There are adequate opportunities for failure at every level of this transfer process. Often receiver managers are subject to pressures that slant the decision-making process toward external objectives that conflict with the demands of the technology and the goals of the providers (Aasen, et al, 1991). In the private sector, the need for profitability would redirect these lane wanderers; more care must be taken to create reliable accountability measures at the government level.

Line operational requirements often leave little time for training. When there is no commitment to training from the receiver manager, ad hoc technology transfer occurs in the organization's spare time.

Often, early project planning neglects the provision of a well-considered counterpart preparation program. Consequently, the technology provider finds himself with a counterpart completely lacking the mastery of even basic skills. Unfortunately, it is not uncommon to find that the technicians provided to install and operate the equipment lack any expertise in technology transfer.

At the training level care must be taken to identify existing skills and define needed skills; to choose appropriate training methods; and to select and maintain an effective system of evaluation - one that will generate the necessary feedback for adjustments in the training process.

PITFALLS IN TECHNOLOGY TRANSFER PROGRAMS

(1) Program Definition

Typical Problems:
- (A) Inadequate needs assessment
- (B) Poorly defined mission statement

(2) Program Design

Typical Problems:
- (A) Project activities do not contribute to the mission statement
- (B) Poor communications
- (C) Overambitious or "Quick fix" Programs
- (D) Ambiguous specifications
- (E) Technology for technology's sake
- (F) Failure to design evaluation prior to execution

(3) Program Execution

Typical Problems:
- (A) Lack of flexibility (human and material resources)
- (B) Selection of services and materials based on cost alone
- (C) Failure to change course when indicated
- (D) Inadequate records of performance

(4) Program Evaluation

Typical Problems:
- (A) Evaluation involves only product, excluding input and process
- (B) Tendency to criticize individuals or departments
- (C) Evaluation results not used in program decision making.